Optimum strategies for hydrogen economy

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- **EU energy strategy** – towards 2050
- **RePowerEU plan** – phase out dependency on Russian fossil fuels
- **The role of H_2 in energy transition** – long-term scenarios from carbon economy to hydrogen economy
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- **Development of optimization algorithms** – advanced simulation tools for large scale integration of sustainable technologies and storage
- **Long-term H_2 strategies for Cyprus** – regional cooperation towards hydrogen economy

1

EU energy strategy

towards 2050

2

Energy transition

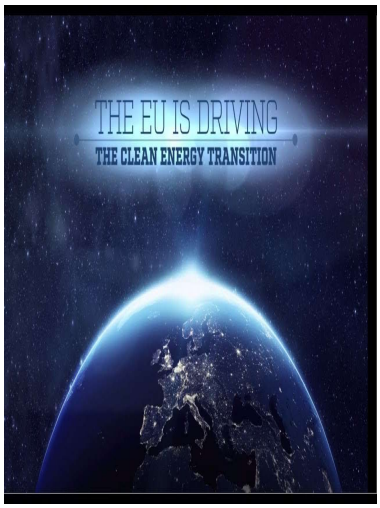
- greenhouse gas reduction
  - EU: climate neutral by 2050
- sustainable production and consumption
- competition in electricity and natural gas markets
- security of supply

3

Energy transition*

Need to:

- Reduce cost of security of supply
- Achieve market integration
- Increase socio-economic welfare benefits



* Poullikkas A., 2013, *Renewable Energy: Economics, Emerging Technologies and Global Practices*, ISBN: 978-1-62618-231-8

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The EU Green Deal and Fit-for-55

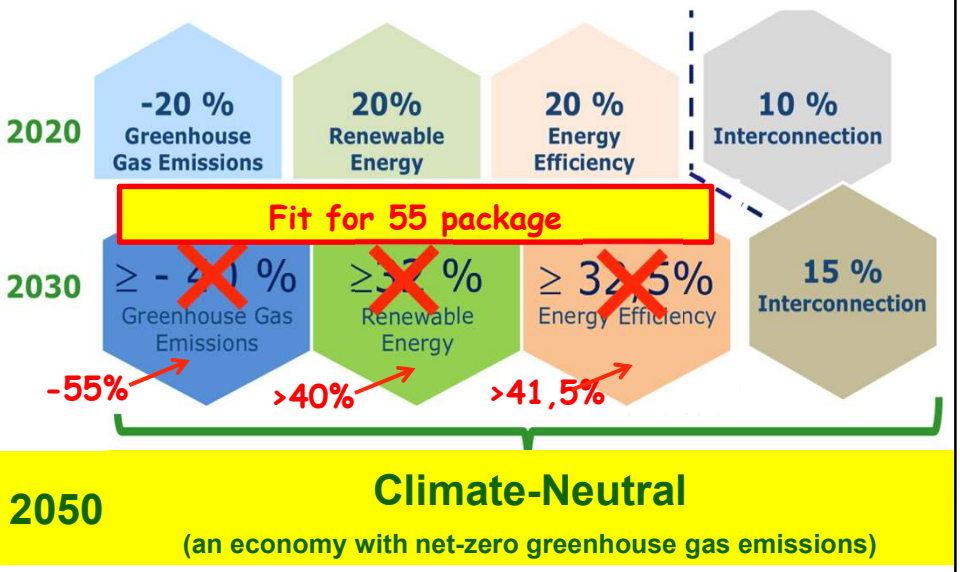
…to reach our targets in a:

- socially fair
- cost-efficient
- competitive

way…

5

EU medium and long term targets



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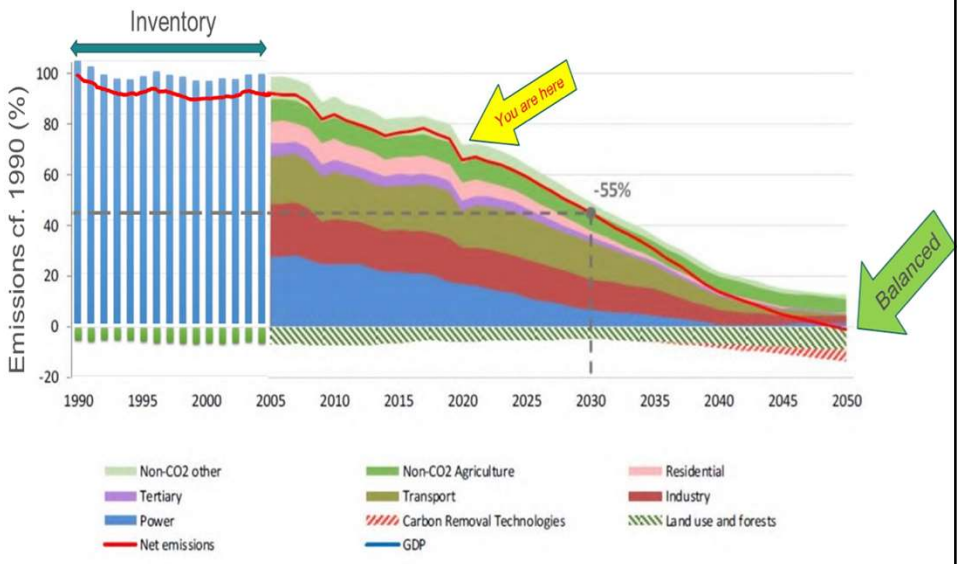
Fit-for-55 strategy



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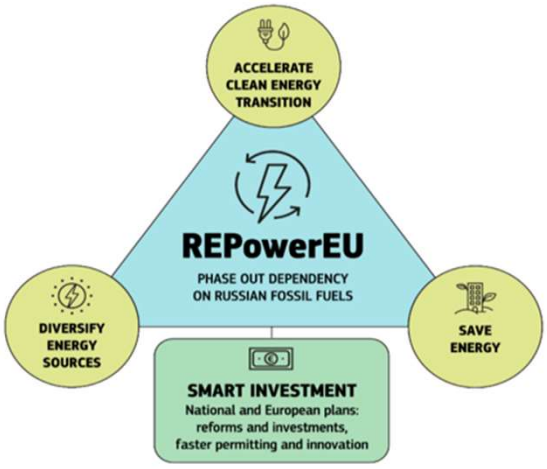
RePowerEU plan

phase out dependency on Russian fossil fuels

8

RePowerEU plan*

Phase out dependency on Russian fossil fuels



* RePowerEU Plan, EU, 2022

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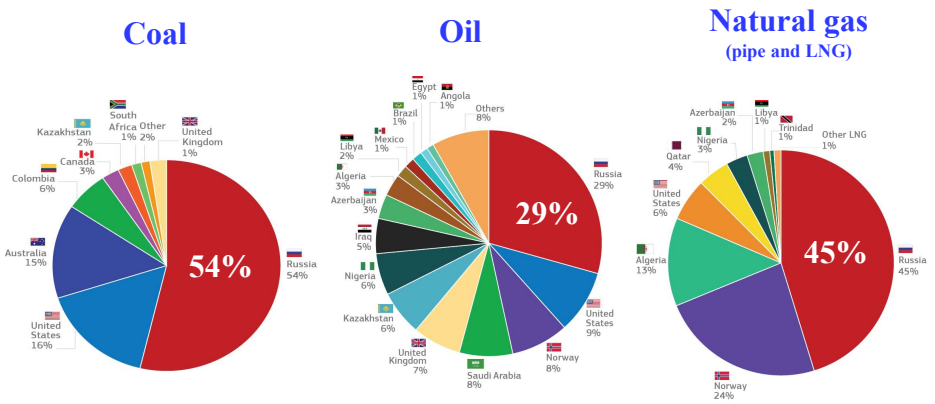
EU energy import dependency on Russia (year 2021)



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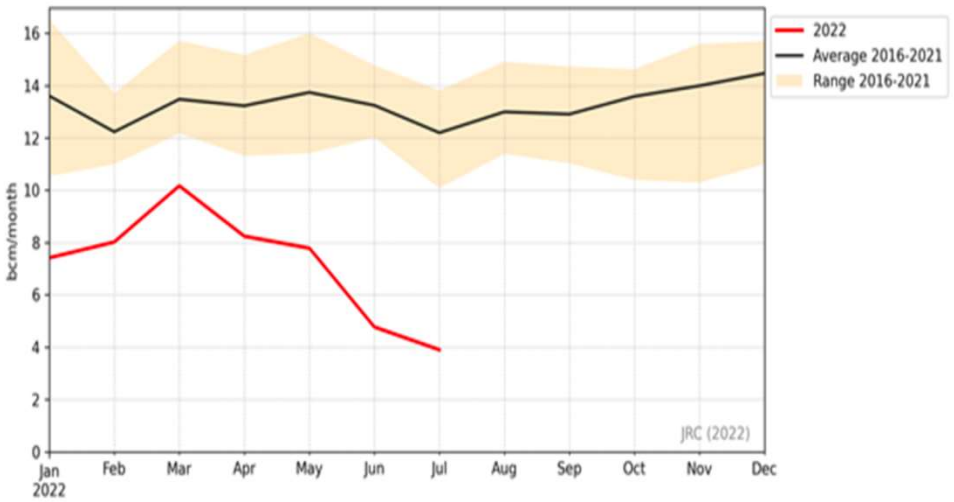
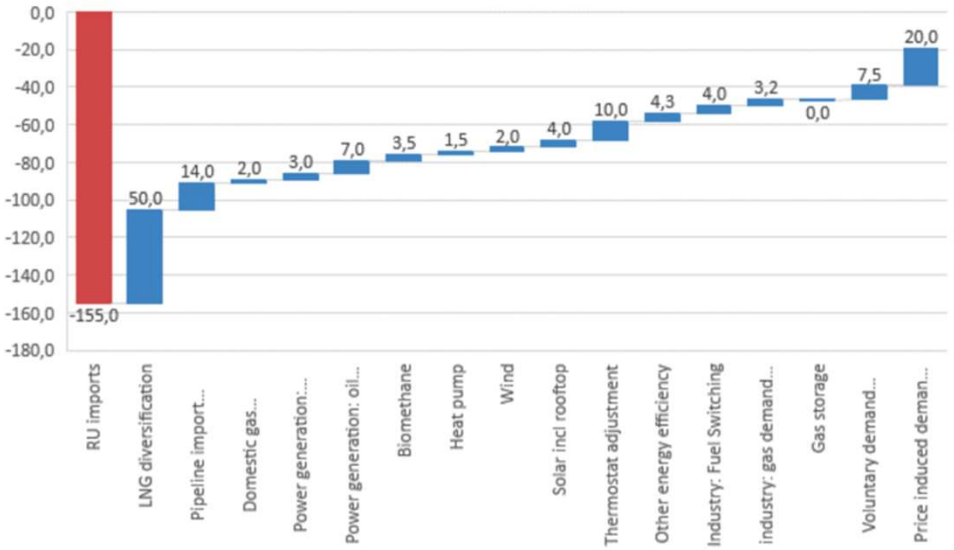
Flows from Russian gas in 2022*



* Save Gas for Safe Winter, EU, 2022

11

Measures to bridge the gap*



* Save Gas for Safe Winter, EU, 2022

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RePowerEU plan*

- **Phase out EU dependency on Russian gas, oil and coal imports**
  - **accelerating the reduction of overall reliance on fossil fuels**
  - **diversifying supplies through the use of LNG**
  - **further developing a hydrogen market for Europe**
  - **speeding up the development of renewables**
  - **completing and improving the interconnection of European gas and electricity networks and fully synchronising power grids throughout the EU**
  - **monitoring and optimising the functioning of the electricity market**
  - **Energy savings**

* RePowerEU Plan, EU, 2022

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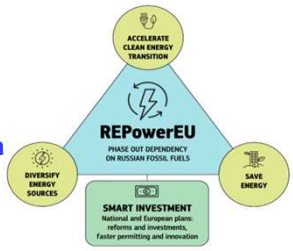
RePowerEU: from goals to actions

- Independence from Russian fossil fuels by 2027
- Increase imports of LNG by 50 bcm
- Increase pipeline natural gas imports by 14 bcm
- Increase biomethane production by 3.5 bcm
- EU-wide energy saving to cut gas demand by 14 bcm
- Rooftop solar to reduce gas demand by 4 bcm
- Heat pumps to reduce gas demand by 1.5 bcm
- Reduce gas demand in the power sector by 20 bcm by deployment of wind and solar



Increase the target of renewable energy from 40% to 45% by 2030

Increase the target of energy savings from 9% to 13% by 2030

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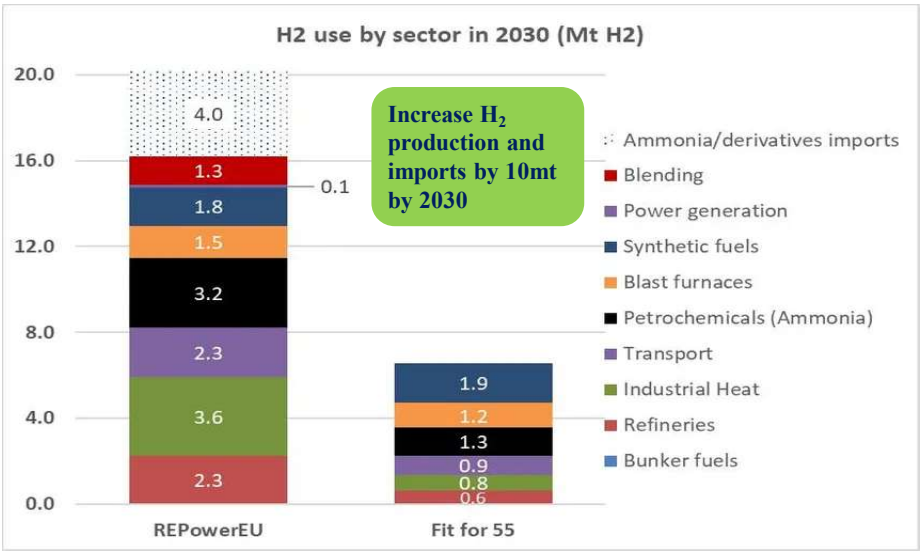
H_2 accelerator*



Increase H_2 production and imports by 10mt by 2030

* RePowerEU Plan, EU, 2022

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The role of H_2 in energy transition

Long-term scenarios from carbon economy to hydrogen economy

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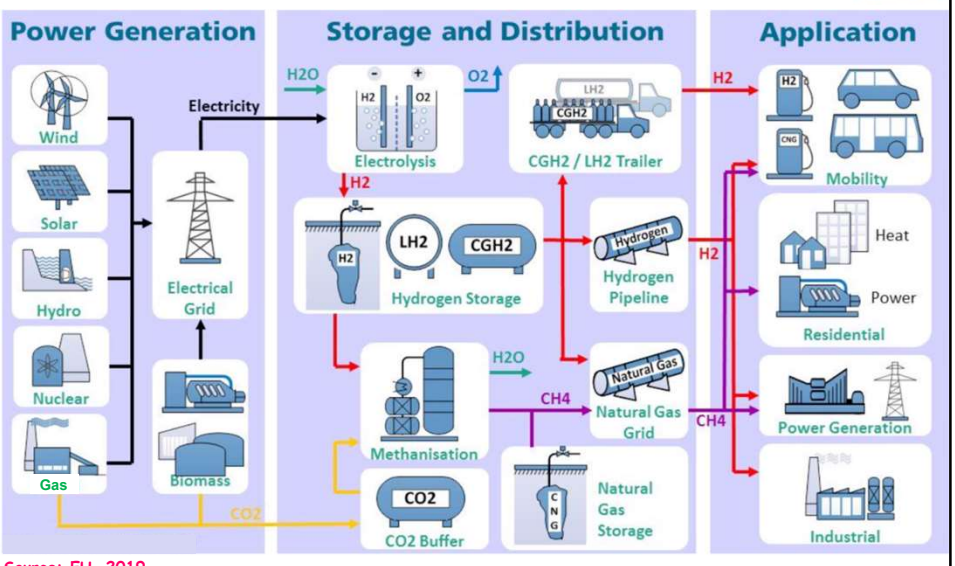
Potential role of hydrogen in the energy transition



Source: EU, 2019

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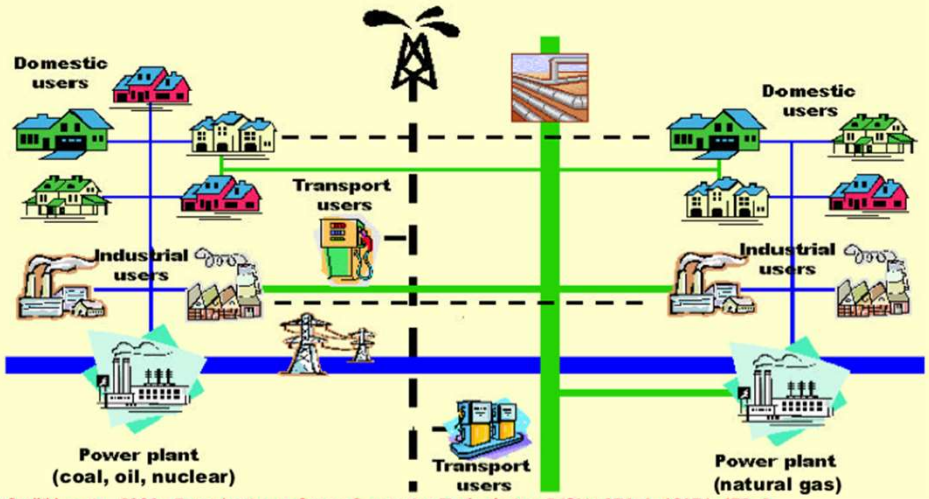
Energy system in 2010

EU energy system in 2010*



* Poullikkas A., 2009, *Introduction to Power Generation Technologies*, ISBN: 978-1-60876-472-3

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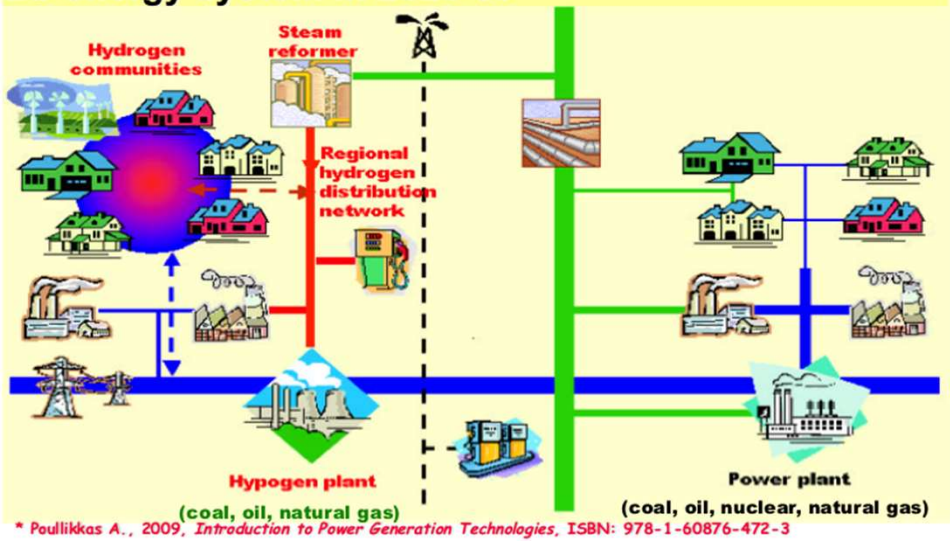
Future energy systems (optimistic scenario)

EU energy system in 2020-30*



* Poullikkas A., 2009, *Introduction to Power Generation Technologies*, ISBN: 978-1-60876-472-3

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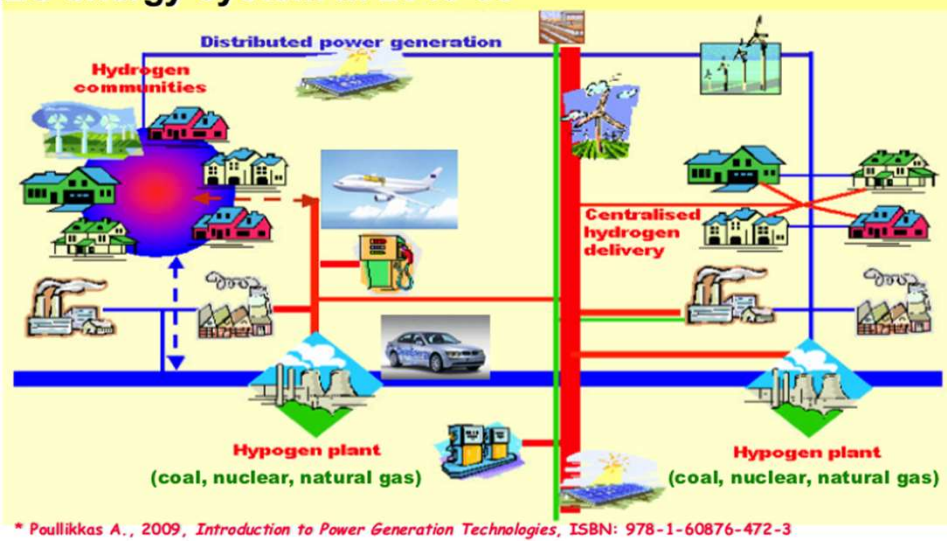
Future energy systems (optimistic scenario)

EU energy system in 2040-50*



* Poullikkas A., 2009, *Introduction to Power Generation Technologies*, ISBN: 978-1-60876-472-3

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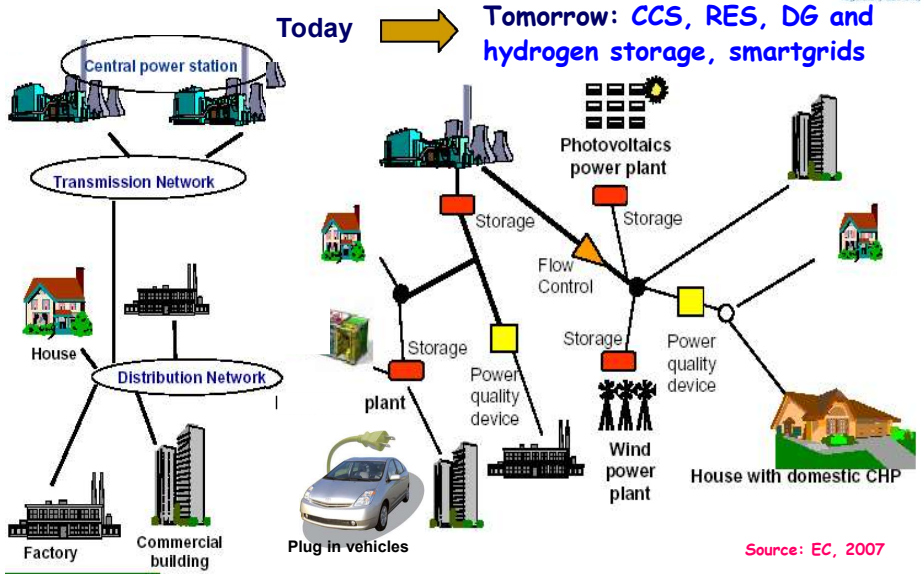
Future power systems



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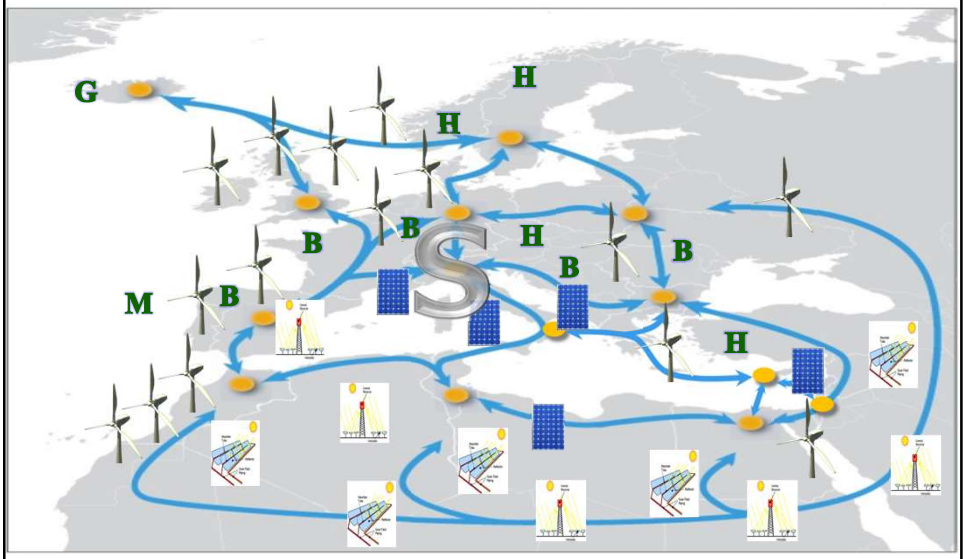
The Super Smart Grid after 2050*
(may allow for 100% RES)



* Poullikkas A., 2013, *Sustainable Energy Development for Cyprus*, ISBN: 978-9963-7355-3-2

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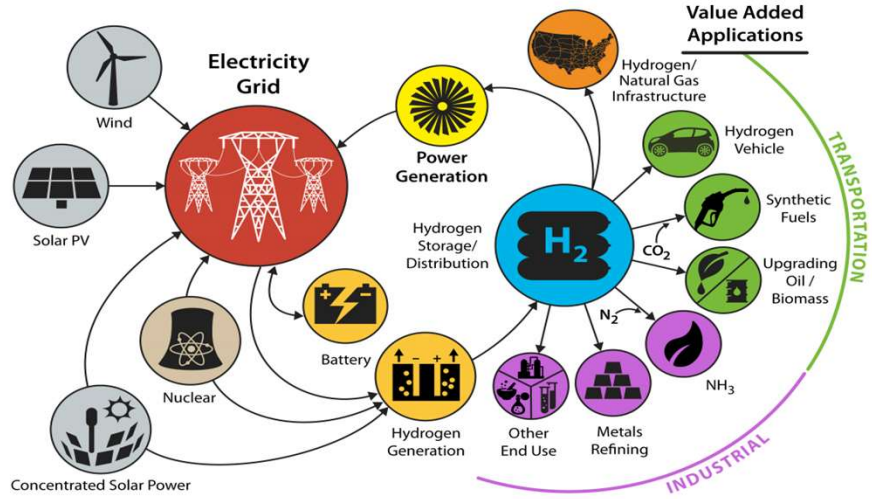
Long term scenarios in Europe

Moving from Carbon economy to Hydrogen economy



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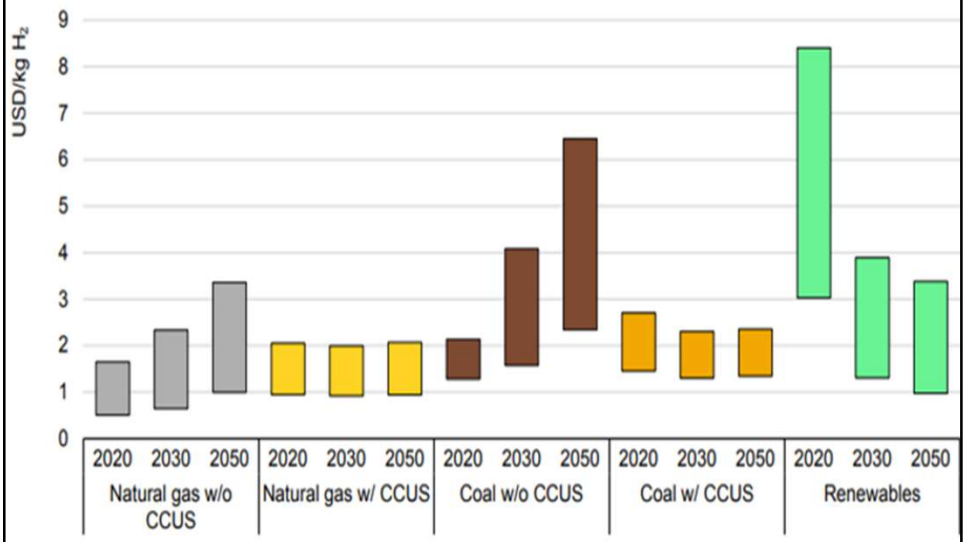
H_2 production cost*



* *The Future of Hydrogen*, International Energy Agency, 2019

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Saudi Arabia $5bn Helios H2 project

- Desert area = Belgium
- 4GW of Wind and PVs

- Production of 650t/day of H_2
- Reduce of H_2 production from 5US$/kg to 1.5US$/kg
- Long-term: Saudi Arabia to become H_2 exporter

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National H_2 strategies

towards 2030-2050

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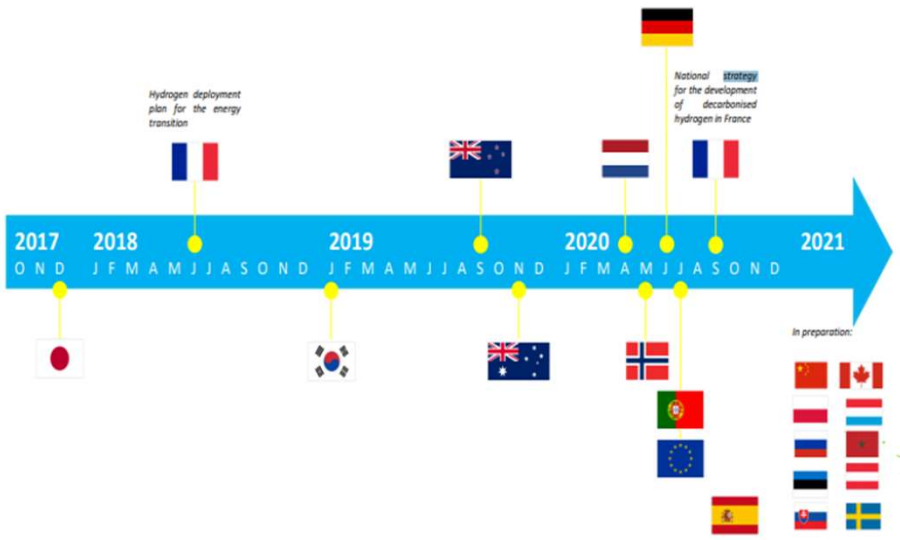
National Hydrogen Strategies*



** Possible regulation of hydrogen networks, ACER 2021*

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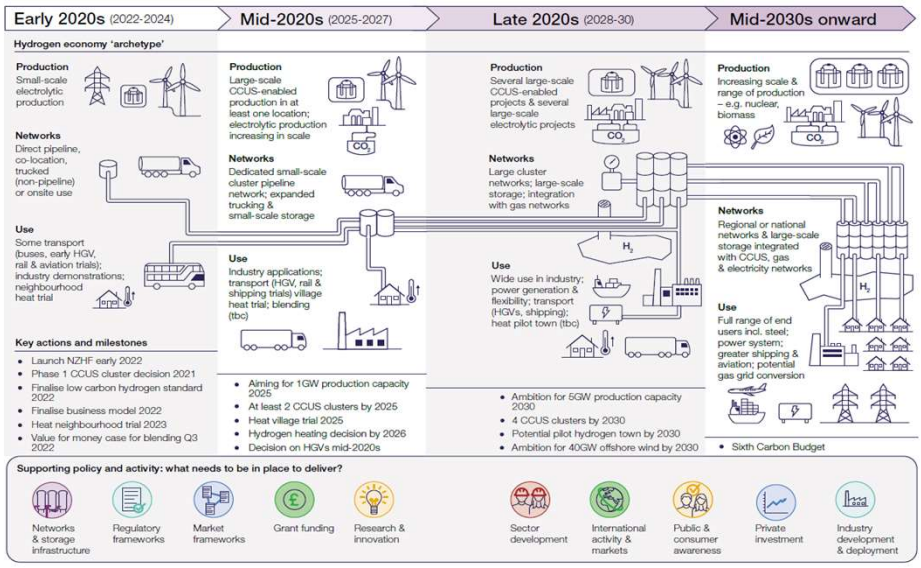
UK H_2 roadmap



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EU H_2 strategy*

Today - 2024	2025-2030	2030
• Installation of Electrolysers: at least 6GW for green H_2 production • Production of green H_2: up to 1mt	• H_2 to become part of the integrated energy system • Production of green H_2: more than 10mt	• Large scale integration of green H_2

** A hydrogen strategy for a climate-neutral Europe, EU, 2020*

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Development of optimization algorithms

advanced simulation tools for large scale integration of sustainable technologies including storage

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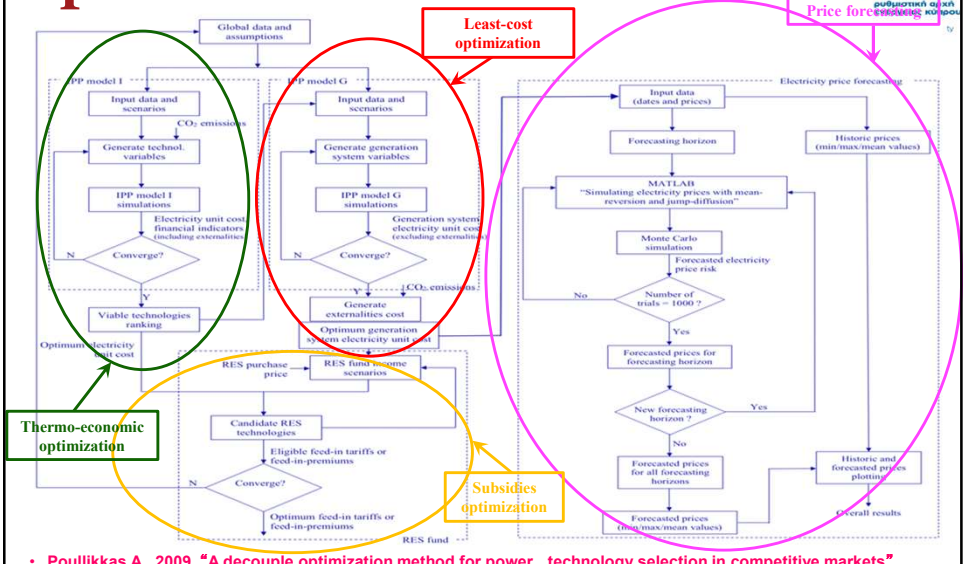
Optimization model*,**



- Poullikkas A., 2009, "A decouple optimization method for power technology selection in competitive markets", *Energy Sources*.

** Poullikkas A., 2018, "An adaptive longterm electricity price risk modelling using Monte Carlo simulation", *Journal of Power Technologies*

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Long-term H_2 strategies for Cyprus

regional cooperation towards hydrogen economy

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Characteristics of isolated electricity systems*

- **High fuel costs**
  - ~ use of oil derivatives
  - ~ high CO_2 emissions (additional cost)
- **Economies of scale cannot be adequately exploited**
  - ~ generation units cannot exceed a certain size since the loss of a unit would mean the loss of a high percentage of the entire system
- **Need to maintain high reserve capacity to ensure power system reliability**

The smaller the electrical system size, the more the expenses will be

* Poullikkas A., 2015, *Sustainable Energy Policy for Cyprus*, ISBN: 978-9963-7355-6-3

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The solution*

- **Increase system flexibility**
  - ~ integrate RES into electricity market
  - ~ use natural gas, storage and RES for power generation
  - ~ promote e-mobility (V2G technology - bidirectional flow of electricity between the electric car and the grid)
- **Establish electricity interconnections**
  - ~ with EU internal electricity market (the island of Cyprus is the only non-interconnected Member State)
- **Production of hydrogen** (energy carrier)
  - ~ from RES and natural gas

* Poullikkas A., 2016, *Fundamentals of Energy Regulation*, ISBN: 978-9963-7355-8-7

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Storage and flexible technologies are the missing links

Energy storage

Flexible technologies

Hydrogen technologies

CERA

Storage, Flexible Technologies and Hydrogen Regulatory Frameworks

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CERA Energy Transition Regulatory Decisions

- **Regulatory Decision 01/2017 (ΚΔΠ 34/2017): A detailed schedule for the implementation of EU electricity market target model**
- **Regulatory Decision 02/2018 (ΚΔΠ 259/2018): The mass installation of an Advanced Metering Infrastructure including smartmeters to all electricity consumers**
- **Regulatory Decision 02/2019 (ΚΔΠ 204/2019): The establishment of basic principles of a regulatory framework for the operation of electricity storage systems in the wholesale electricity market**
- **Regulatory Decision 03/2019 (ΚΔΠ 224/2019): The redesign of the power grid to become smart and bi-directional in order to allow integration of large quantities of renewable energy sources in combination with energy storage systems**

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Regional primary energy sources

Indigenous energy sources

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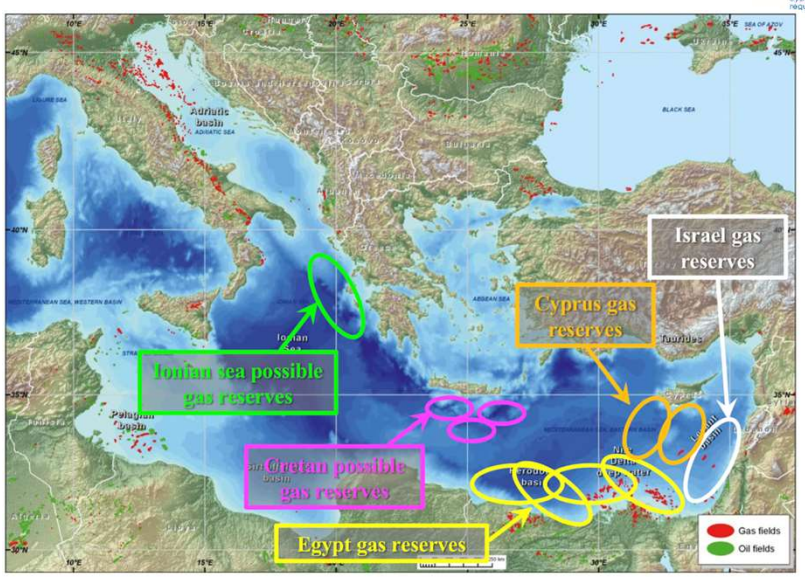
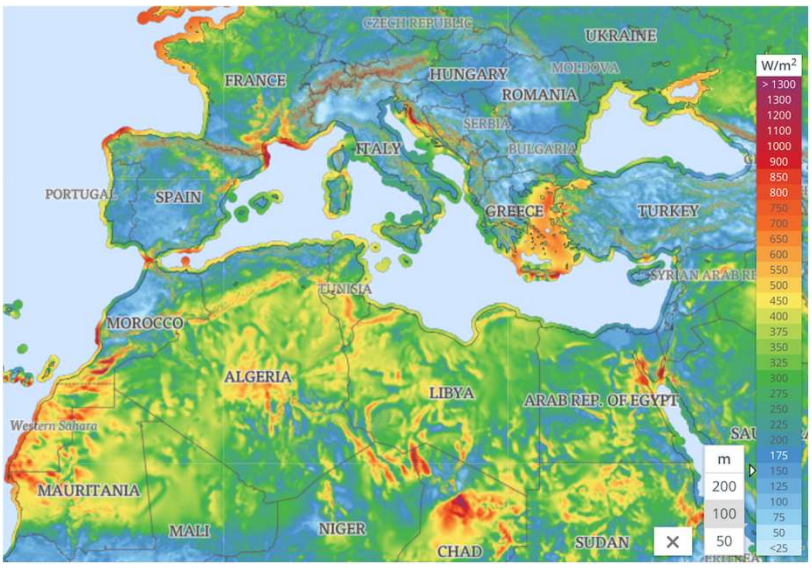
Gas reserves in SE Mediterranean region*



* A. Belopolsky, *et al.*, 2012, "New and emerging plays in the Eastern Mediterranean", *Petroleum Geoscience*

40

Wind potential in SE Mediterranean region*



* The Global Wind Atlas (https://globalwindatlas)

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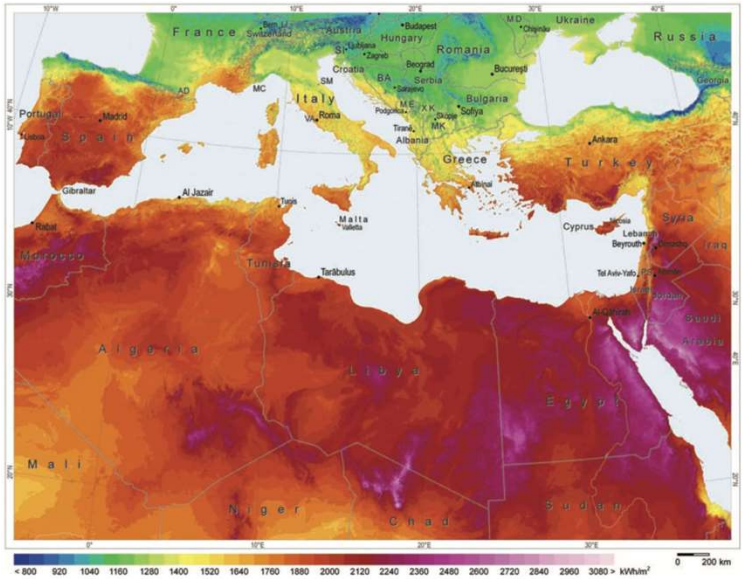
Solar potential in SE Mediterranean region*



* Easac & Pihl, Erik. (2011). Concentrating Solar Power: Its potential contribution to a sustainable energy future

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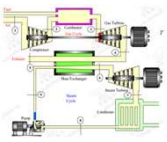
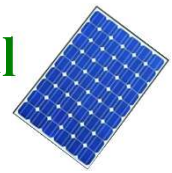
Main indigenous energy sources in SE Mediterranean region

- Natural gas



- Wind potential

- Solar potential



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Energy transition by 2050

Cyprus' energy system:

- smart and digitised
- flexible
- decentralised
- electrically interconnected
- interconnected gas and/or hydrogen pipelines

Integration:

- hydrogen in all energy sectors
- renewable energy sources
- storage energy systems
- electric mobility

Transition of Cyprus from the current carbon economy to hydrogen economy by the year 2050

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Cyprus H2 strategy?

- Recognition of hydrogen as a key component of the energy mix for 2030 and up to 2050
- Creation of a long-term national energy strategy considering hydrogen
- Creation of a legislative framework - allow the introduction of participants in H_2 market
- Harmonization of national regulatory framework with the relevant European Directives
- Targeted measures to kick-start the hydrogen value chain: production; transport and storage; use in final consumption

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Development of regional energy strategy ?

- Horizon up to 2060
- Development of strategic plan for SE Med region:
  - ~ Electrical interconnections
  - ~ Pipeline interconnections (or virtual pipelines)
  - ~ Integration of sustainable technologies and storage
  - ~ Use of hydrogen after 2030
  - ~ Hydrogen production
    - From natural gas
    - From renewables
- Energy exporters to EU

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Additional Slides

The energy transition cost

Towards 2050

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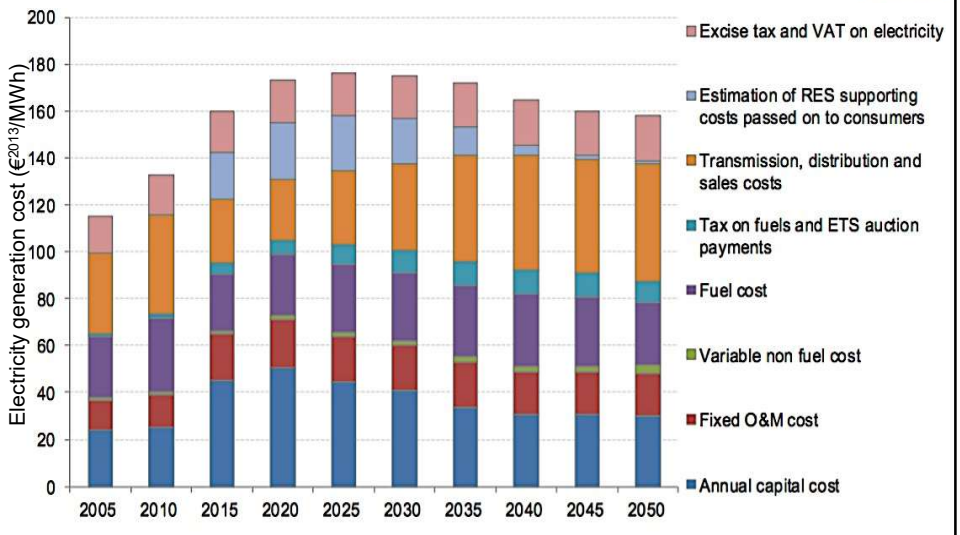
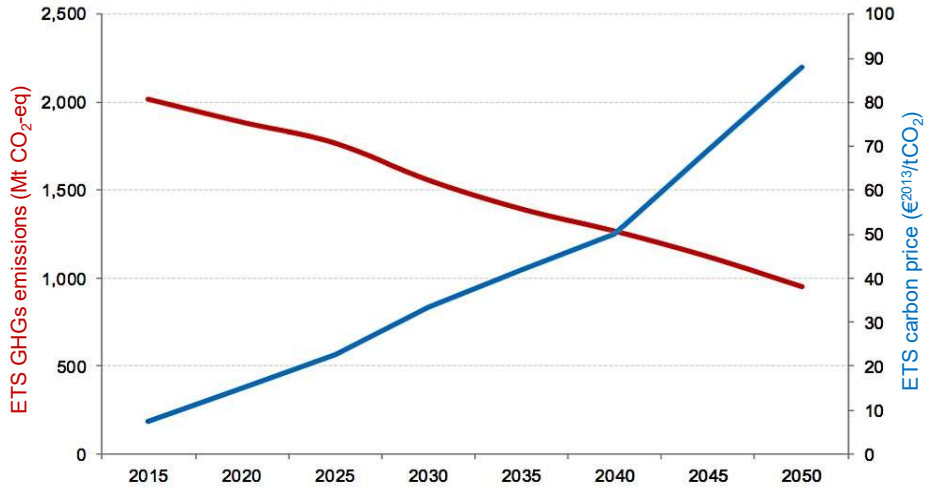
EU reference scenario 2016



Source: PRIMES

49

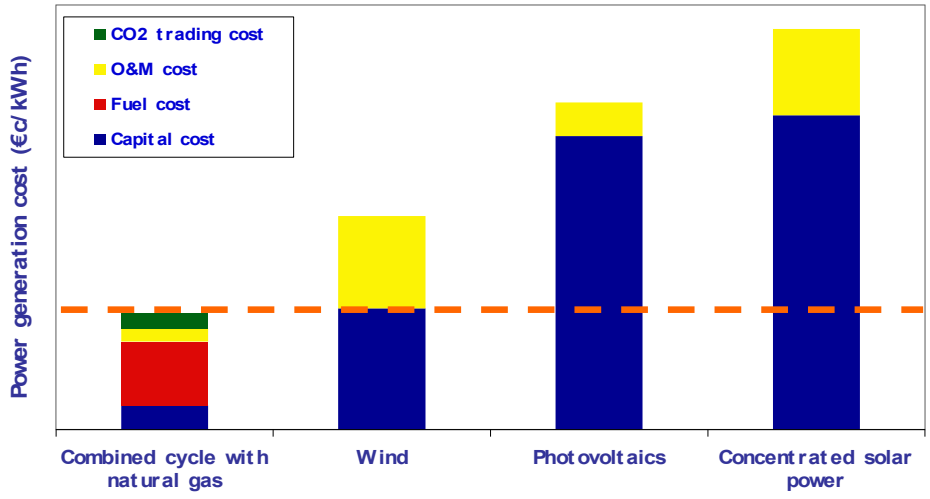
EU reference scenario 2016



Source: PRIMES, GAINS

50

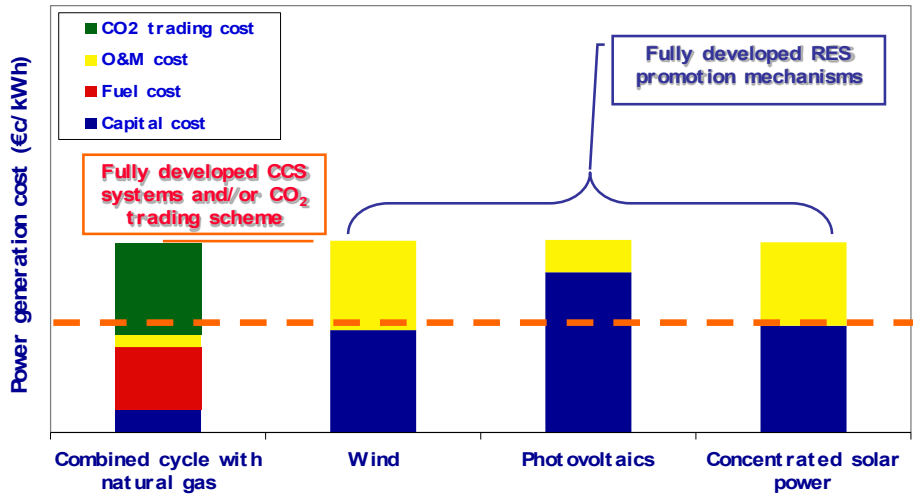
Power generation cost (year 2010)*



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

51

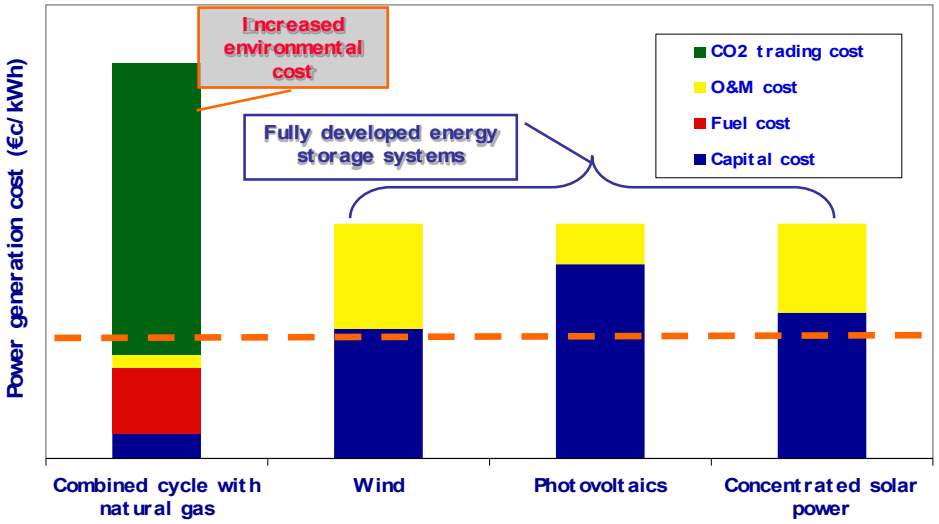
Power generation cost (year 2020-30)*



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

52

Power generation cost (year 2040-50)*



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

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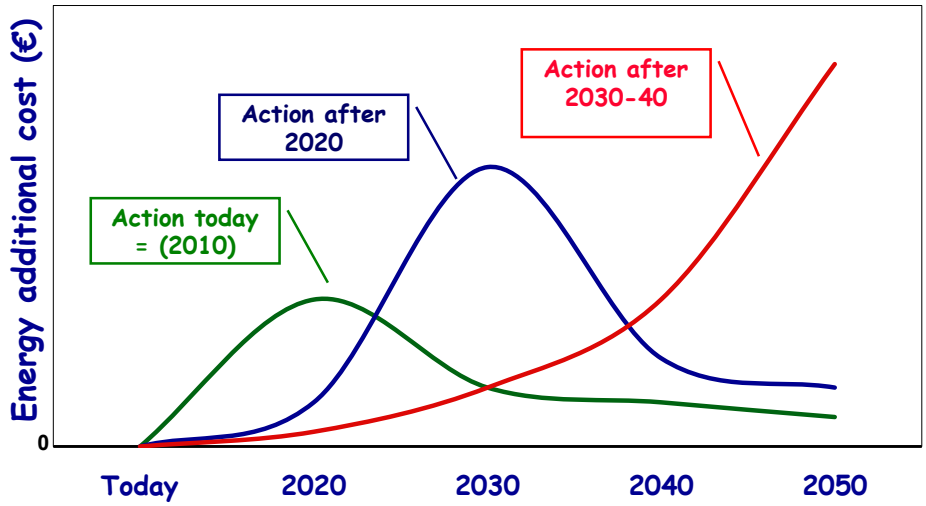
Future energy cost* (for EU only)



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

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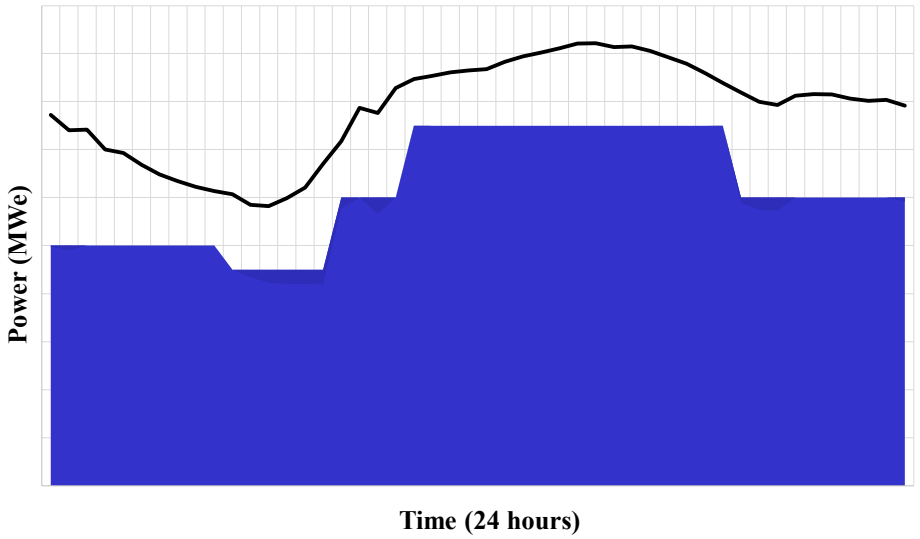
Electricity market operation

EU target model

55

Electricity market operation

- **Forward market**



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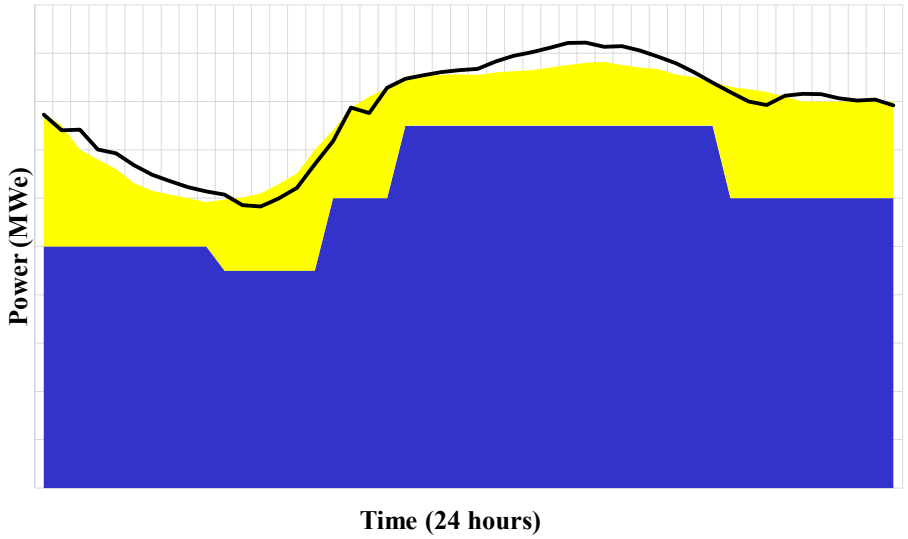
Electricity market operation

- **Forward market + Day ahead market**



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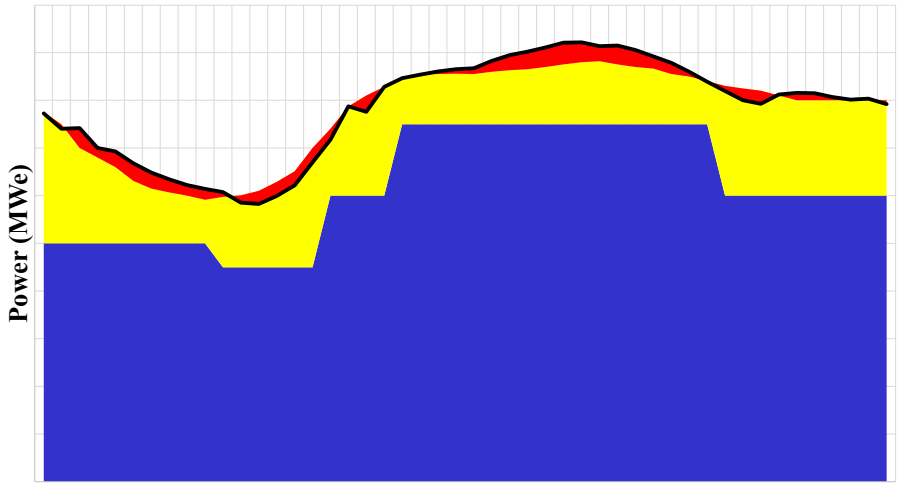
Electricity market operation

- **Forward market + Day ahead market + Balancing market**



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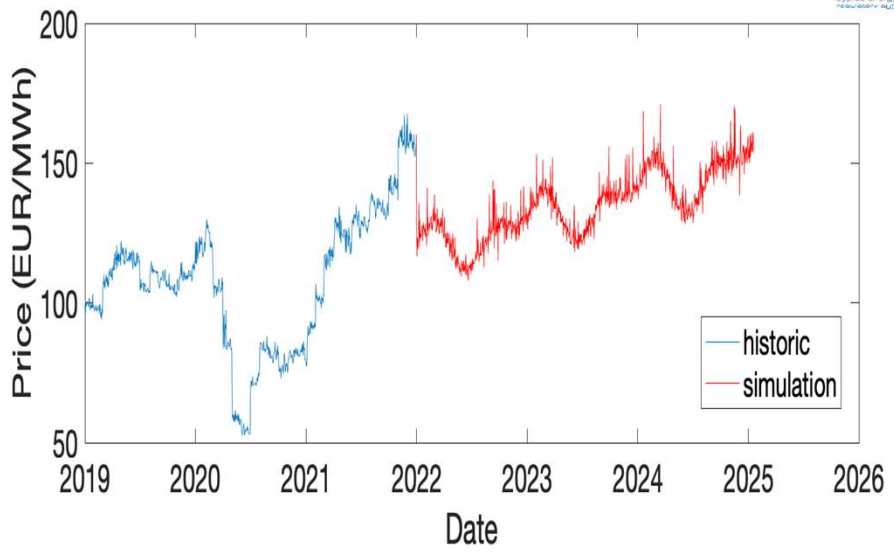
Actual and simulated prices*



* Poullikkas A., 2018, "An adaptive longterm electricity price risk modelling using Monte Carlo simulation", *Journal of Power Technologies*

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EU electricity market target model

Integration of RES*: LCOE *vs* Reliability

* Nicolaidis P., Chatzis S., Poullikkas A., 2018, "Renewable energy integration through optimal unit commitment and electricity storage in weak power networks", *International Journal of Sustainable Energy*

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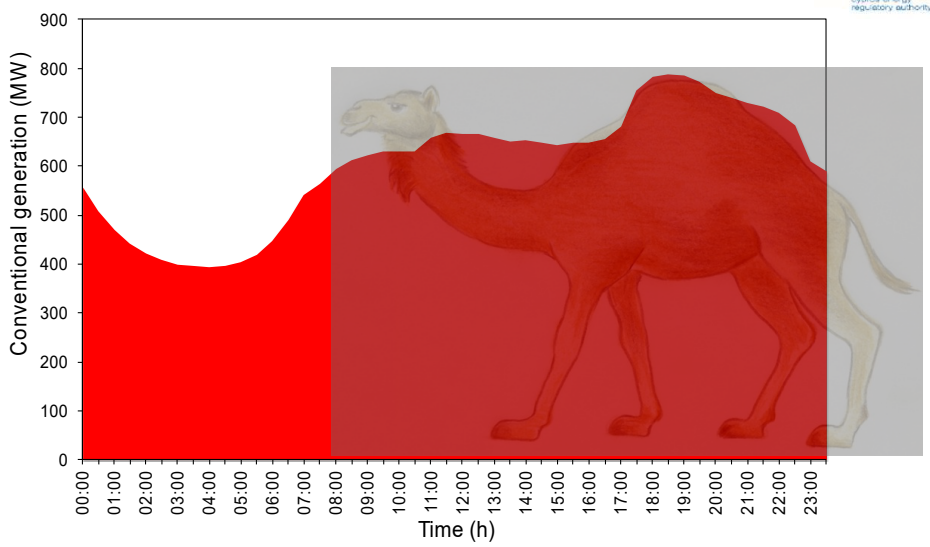
Daily load curve (the 'camel curve')*



* Poullikkas A., 2016, "From the 'camel curve' to the 'duck curve' on electric systems with increasing solar power", *Accountancy*

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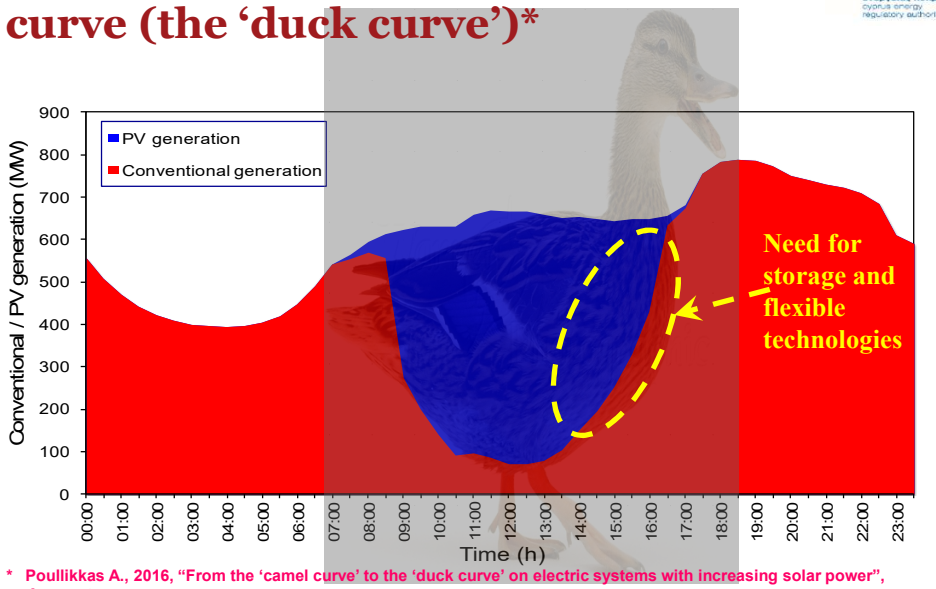
Effect of PV generation on load curve (the 'duck curve')*



* Poullikkas A., 2016, "From the 'camel curve' to the 'duck curve' on electric systems with increasing solar power", *Accountancy*

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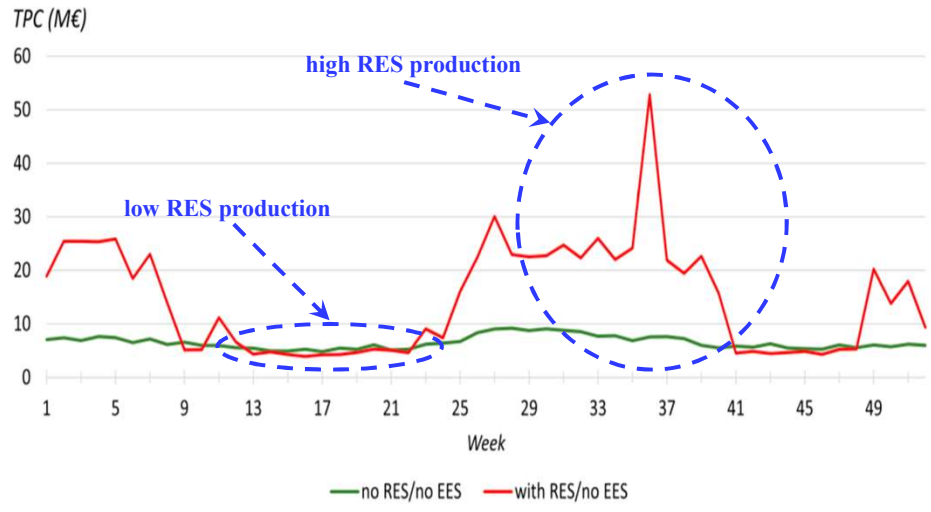
Cost of reserves with RES production*



* Nicolaidis P., Chatzis S., Poullikkas A., 2018, "Renewable energy integration through optimal unit commitment and electricity storage in weak power networks", *International Journal of Sustainable Energy*

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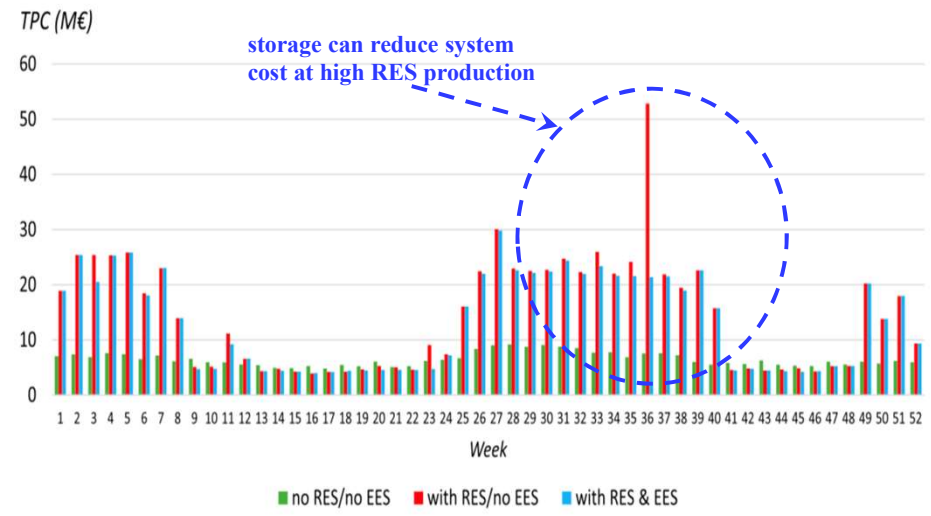
Integration of storage*



* Nicolaidis P., Chatzis S., Poullikkas A., 2018, "Renewable energy integration through optimal unit commitment and electricity storage in weak power networks", *International Journal of Sustainable Energy*

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